BEST PRACTICES

Project Engineering a Machinery Management System

How to make sure your next project delivers the tools you need to properly protect and manage machinery

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The opportunity – a new project

If you are an equipment user concerned about machinery assets, it's likely that you are busier than ever because of manpower cuts and broadened responsibilities. What happens when a new plant or upgrade project comes along? You probably view it as a chance to install better machinery protection and management tools – tools that will help you work more efficiently and effectively. However, even if given the opportunity, will you be able to effectively influence the details of the project to ensure systems that are truly "best practice" get installed? How will your philosophies and preferences be communicated to the project engineers and managers, some or all of whom may be of another discipline, in different departments or companies, or in other states or countries? This article provides insight into how you can succeed.

The challenge – ensuring your voice is heard

Although others may have the responsibility for design and specification of these systems, your ability to fulfill the asset management objectives of your organization will be greatly affected by their choices. If you don't voice your needs during the relatively brief period during which basic system functional specifications are assembled, your long-term capabilities will default to the lowest common denominator, as defined by others.

Project engineers and managers – even your corporate machinery consultant or operations representative – often evaluate machinery protection and management equipment from a different perspective than you do. They often focus on price, size, ease of specification, and the philosophy of "we've always done it this way." These criteria aren't necessarily wrong; but, if they become the overriding criteria, less obvious (but nonetheless crucial) features may be compromised or left out.

Thus, the first step in a successful project is relatively simple, but cannot be over-emphasized: *don't assume that others will (or can) represent your interests*.

Typically, Bently Nevada will share your interests, but sometimes we can't easily represent them, particularly for "traditional" projects where our scope of supply only encompasses hardware and software – not applications engineering, system design, and project management. In these cases, our input is sometimes not solicited or allowed until late in the project. Furthermore, by the time we are asked to participate, our ability to influence project details is long past, and system evaluation has been reduced to price comparisons only. There are two ways to address this.

Approach #1 – fully utilize Bently Nevada's service organization

The first way to ensure your voice is heard is simply to outsource the entire project to someone who shares your machinery protection and management philosophy.

To support this, Bently Nevada has restructured and augmented its service organization along the lines of an engineering services company. You've relied on us for years for many individual facets of project work, including cabinets, Factory Acceptance Testing of machines and instrument systems, mechanical and electrical system designs, site supervision, and field system commissioning. Our new organization makes it possible for us to participate as an alliance partner with your project design team. Bently Nevada can "fill the gaps" and provide knowledgeable and cost-effective project engineering and management services. More importantly, we can eliminate losses and inefficiencies related to circuitous routing of product and field installation documentation. We

can also manage software updates and hardware upgrades during the extended project cycle and can ensure that the often-neglected commissioning and training services are optimally coordinated. It is only proper that the company that designs and builds these sophisticated engineered systems should actively participate in their application and installation.

In an ideal world, this is our preferred solution for virtually all customers. The likelihood that your system will meet your needs (and will deliver a faster return on investment) is increased when your macro objectives are communicated and the numerous details of system implementation are left to us.

This approach is being adopted by a number of our customers. However, we understand that we have to provide the levels of service that meet your individual approaches and strategies. Our services are scalable to support this; they can range from providing only hardware and software to be installed by others, to the full "turnkey" approach described above, to various levels in between.

Approach #2 – "selling" your own project management team

If you do choose to manage the project-related details yourself, it is still essential that you clearly and convincingly convey your macro objectives to your project management team. Thus, the second way to achieve project success is to be fully prepared to articulate your perspective on the need for machinery protection and management systems, and basic system capabilities and architecture. The remainder of this article provides the supporting information you will often need to "sell" your own project management team on the value of machinery management and the proper implementation of it.

FAQs

If you have found yourself at a loss for the right words, the following answers to "Frequently Asked Questions" will help you eliminate misconceptions and align the thinking of your project engineers and managers with your own perspective of this equipment and its installation. The answers include how your preferred vendor *can* have a significant impact on the project, and in a way that successfully accomplishes both your own and the project's goals.

Isn't Predictive Maintenance or Condition-Based Maintenance something we can wait to worry about until the plant is running?

Some project managers do consider Predictive Maintenance (PM) and Condition-Based Maintenance (CBM). However, it may be relegated to a line item for the purchase of a portable data collector. That is an easy choice for a project manager to make; it is usually an insignificant expenditure relative to total project cost, and is a stand-alone item that has no design or integration requirements. However, how effective a machinery management tool will it be?

Let's review the definition of a machinery management system: "Products that provide data and information that is interpreted and applied by people to correctly operate, maintain, and monitor the condition of their machinery." The definition infers that machinery decisions are made, based on data and information. More and better data and information logically translates into better machinery decisions. A walk-around machinery management program relies heavily on people and time for the quantity and content of data. Consequently, the logical way to provide better decisions is to throw more man-hours at portable data collection. The problem with this is that additional manpower is not available. Quite the contrary, the only viable solution to today's manpower shortages is to automate time-consuming, repetitive tasks. So we see that a portable data collector, when applied to a program involving a large number of machines or expensive critical machines that warrant close attention, is not in step with today's business environment. If your plant really aspires to long-term profitability, the obvious choice is to add an online machinery management system to the infrastructure of your new construction or control system upgrade project.

New construction and upgrades are the most cost-effective "window of opportunity" you have for installing online machinery management systems. The following items are all luxuries not afforded to the person retrofitting such systems into a completed and operating facility:

- Economies of scale.
- Availability of labor.
- Easy integration into network and control system designs.
- The chance to easily locate and route the necessary components and cables.

If you are concerned that you can't instrument all of the machines you want to, comprehensive systems like Bently Nevada's System 1™ will allow for portable collector data to be integrated into the same database and display formats used by online monitoring systems.

Won't the OEM take care of specifying this?

Most Original Equipment Manufacturers (OEMs) do a good job of providing *machinery protection* systems. In fact, Bently Nevada works closely with many OEMs to specify

proper protection systems. However, these are not management systems, but rather products that provide shutdown of a machine or return it to a safe or nondestructive mode of operation without human intervention. As such, they are machine-specific. An OEM doesn't typically focus on the overall Decision Support℠ infrastructure of your plant, but rather on the automatic shutdown of the machine(s) they provide. Unless stipulated in their contract, OEMs are not usually concerned with your overall machinery management strategy.

A project needs to coordinate the protection systems provided by multiple OEMs. This not only ensures that proper hardware and connections are provided for the machinery management systems, but also guards against a patchwork of several vendors' transducers and protection systems, each with its own architecture and hazardous area methodology. This is increasingly important as plants employ performance monitoring (Bently PERFORMANCE™) and Decision Support℠ systems (Machine Condition Manager™ 2000). Operation and training issues dictate that common systems provide information from different machine types and manufacturers.

Can't the process control system (e.g., distributed control system or programmable controller) perform machinery management functions?

This is a common misunderstanding. The raw data of control systems is discrete status (on/off) and proportional values (temperature, pressure, flow, level, etc.). Unlike many of these proportional values whose information content requires relatively small bandwidths (often 10 Hz maximum), vibration transducers provide information content requiring a *much* larger bandwidth – typically 10 kHz or more – that cannot be addressed by a process control system. Really meaningful machinery data and information cannot be extracted from looking only at corresponding proportional vibration level values. Even a trend of these values only depicts historical levels, and, by itself, little else about the cause or nature of the vibration. Overall vibration amplitude is suitable for machinery protection. Indeed, this is one of the proportional values that a vibration monitor uses to generate alarms. However, a machinery management system needs vibration characteristics (shape, frequency, phase, direction, and so on) to provide meaningful data and information about a machine's operation. It is important to understand this distinction, as illustrated by the following example.

Consider a machine where the vibration level increases with

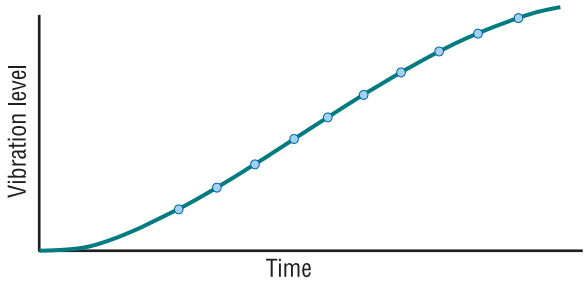

Figure 1. Vibration trend of a machine during startup.

speed, and you would see the trend plot shown in Figure 1. A control system samples the vibration level at an interval corresponding to its scan rate, as is indicated by the dots in the trend plot. If the level is higher than it should be, that indicates an abnormality and might even trigger an alarm or a shutdown relay in the protection system. However, not much would be known except that the vibration is high.

Now, consider how a machinery management system samples the data. Taking just one of those dots, the system sam-

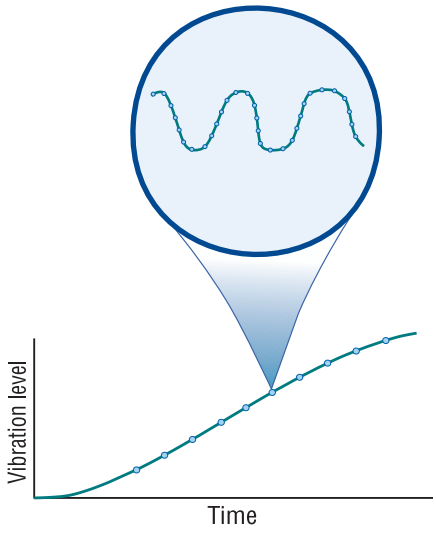

Figure 2. The machinery management system samples the vibration waveform, not just the overall vibration, at 128 samples per shaft rotation. This provides more information, which assures more effective decision making.

ples the transducer signal 128 times per revolution for eight shaft revolutions. There are specific reasons for choosing this interval and duration of sampling [1]. Note that this is a snapshot of the shaft's position relative to the tip of a proximity probe (not the vibration amplitude or level) every 1/128th of a shaft revolution (Figure 2). At a typical shaft speed of 3600 rpm, this sampling is extremely rapid. These analog samples are digitized and placed in a memory buffer before

being sent, on demand, to a machinery management workstation computer.

A level measurement by a process control system (one dot in Figure 1) would be four bytes of information. The digitized waveform and supporting information associated with this point is approximately 100,000 bytes of information. A good analogy to this 25,000:1 ratio is the amount of fuel in a large dual-tank semi trailer truck compared to the amount it takes to fill your lawnmower.

This is just one transducer. To correctly assess machine behavior, the same sampling must occur simultaneously on each transducer on the machine. This high speed "parallel" data collection is an essential feature of good machinery data acquisition systems, but would quickly bog down a control system and is somewhat foreign to its sequential scanning architecture. Don't let the system architectures designed for controlling the process limit the information required for proper machinery management and decisions.

Isn't trending vibration levels in the process control system good enough?

Continuing with the above example, there is a marked difference between the data from the control system and the data from the machinery management system. Diagnostic plots like those shown in Figure 3, in conjunction with trends and process information, enable a Machinery Diagnostics Engineer or a Decision Support℠ software program to translate the vibration characteristics into Actionable Information℠. This information supports decisions regarding:

1. What part of the machine is deteriorating
2. How severe the problem is, how long the machine can operate under the current conditions
3. What process changes might be made to alleviate the situation
4. Whether it should be restarted after it was automatically or manually shut down on high vibration.

This information should also be readily available, via local and wide-area networks, to others who can assist with or confirm the decisions you make.

Aren't such systems really optional? It seems like we could do without such "frills," or add them later.

While it is true that project costs can be saved by removing such systems from the project's scope, this is almost never an enlightened business decision when the ongoing needs of the plant are considered. Nobody would seriously suggest removing the process control system from the scope of a plant, opting instead for some kind of basic "process protection system" by itself. However, that is how machinery is sometimes approached – that it is merely enough to "protect it" rather than "manage it." Remember, there is a very real cost associated with lack of proper machinery management capabilities. How expensive will the inability to make informed machinery decisions be to the plant once it is operational? This must always be the overriding criteria when assessing the value of a proper machinery management system. For many of the projects we are involved in, just a few hours of lost production will immediately eclipse the cost of the machinery protection and management system. Also, as addressed in a later question, the cost to retrofit a system is always significantly higher than the cost to install it concurrently with the machinery protection functions.

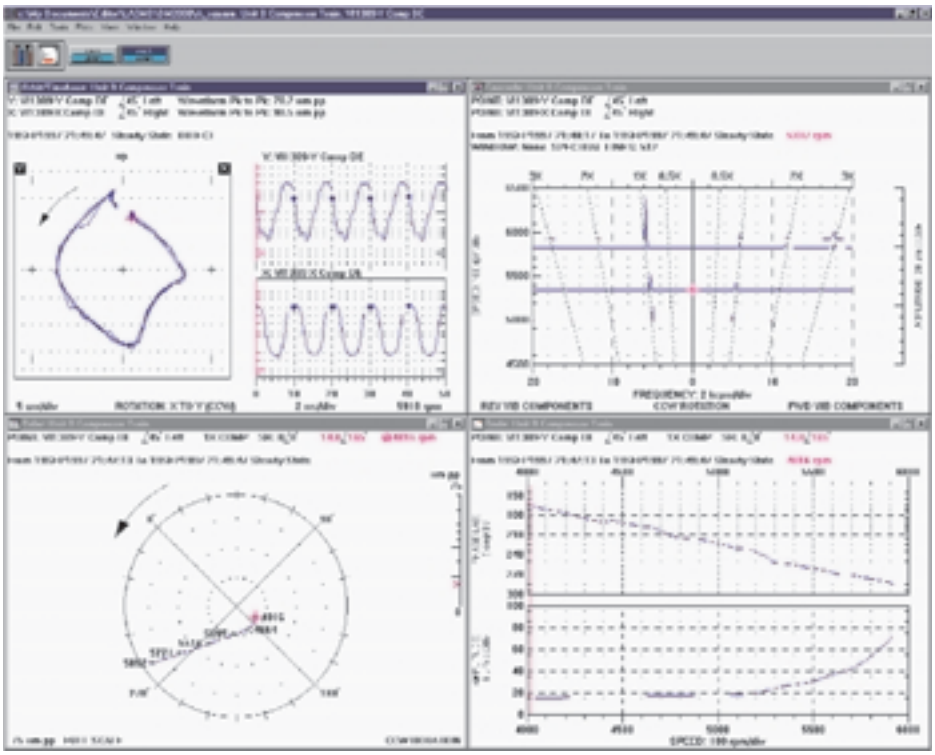

Figure 3. Diagnostic plots from the DM2000 software program are the foundation for Actionable Information℠.

Can't we connect a Bently Nevada machinery management system to our non-Bently Nevada protection system?

It is possible, but installation will be complicated and tedious, far more expensive than connecting to a Bently Nevada protection system, and the system's functionality will be limited. Two premises are fundamental to an understanding of why this is so.

First, a protection system performs functions that are essential to the machinery management system. Vibration amplitudes (levels) are calculated from the sensor measurements, and eventually trended in the machinery management system. Alarm levels are set to communicate when a machine or machine component is in distress. Transducer integrity checking, or "OK" circuitry, helps administer the transducer system on which the protection and management systems depend. Duplicating these functions in the machinery management system would add unnecessary cost and duplicate hardware, result in conflicting measured levels, and require the management of duplicate sets of alarms.

Second, a good machinery management system adjusts its data collection, data storage, and data movement based on the condition of the machine. If the protection system senses a vibration level that exceeds an alarm setpoint, you want the machinery management system to save a waveform sample at the moment the alarm occurs. If an unanticipated shutdown occurs, you want the machinery management system to rapidly capture transient data at set speed intervals as the machine coasts down [2].

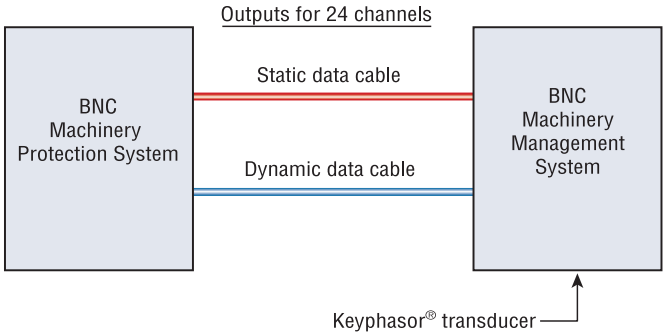

Figure 4. Two cables and four connectors carry data from 24 channels in a BNC machinery protection system.

The communication between a Bently Nevada machinery protection system and the Data Manager® 2000 System is accomplished with two cables and mating multi-pin connectors (Figure 4). One of the connectors carries the raw transducer outputs, and the other carries digital status and level information. Other manufacturers' monitoring systems can be connected to Data Manager® 2000 using a TDXconnX™ adapter. However, the protection system must have proportional (4-20 mA) recorder outputs for each channel, two levels of alarm relay outputs for each pair of channels, a buffered and unfiltered transducer output for each channel, and up to four Keyphasor® signals (Figure 5). For a 24-channel system, this equates to over 125 color-coded wire terminations on the back of the protection system. All these inputs must be isolated from the machinery shutdown signals and circuitry to ensure that the machine protection is not compromised. If there is insufficient I/O available from the protection system, it may or may not be possible to add it. Even with complete I/O, this system will have diminished functionality and accuracy relative to that afforded by the two-cable connection to the Bently Nevada racks. Considering this, some customers with third-party monitoring systems have resorted to the (more economical) purchase of a Bently Nevada protection system to replace or run in parallel with their existing protection system.

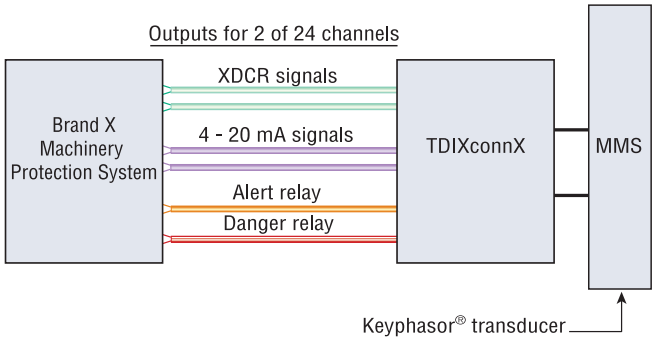

Figure 5. Six cables and twelve connections needed to carry data from only two channels in hybrid system.

Vibration transmitters are an attractive option to the instrument engineer who considers vibration as just another process measurement. In an attempt to interface a machinery management system to vibration transmitters, buffered signal outputs may not be available, not to mention the other inputs described above. In general, vibration transmitters aren't the low-cost option they appear to be [3], and are very problematic from a machinery protection and management standpoint [4].

If you specify Bently Nevada systems from the beginning for both protection and management, you will get a system that is better integrated, easier to maintain, and costs less. The most advantageous time to do this is during a project, not afterwards.

Why bring process variables into the machinery management system?

Process conditions are often responsible for the onset of machinery problems. The ability to view and correlate process trends with vibration trends and plots is a powerful diagnostic tool for understanding your machine's behavior. Process variables are factored into Machine Condition Manager™ 2000 software's rule sets for fault diagnosis and are used by Bently PERFORMANCE™ to provide an integrated machine health and performance package. As described earlier, moving the bandwidth-intensive machinery data to the control system is not practical. It makes more sense to move a smaller amount of process proportional values to the machinery management system, where it will be available for distribution with the vibration data to remote viewers. Using today's network technologies, it is possible to retrieve process data from the control system or plant historian with an insignificant hardware investment. Time-stamping and time synchronization capabilities make the vibration/process correlation more accurate than ever before.

Knowing this, is there any advantage to bring bearing temperatures in through the protection system (as opposed to the control system)?

Yes. The basic premise is that the alarms and process variables will be most useful during a quickly occurring machine transient or problem. As mentioned above, the machinery management system adjusts its sampling rate during an alarm or machine startup/shutdown, and this sampling rate is faster than the sampling rate of the process control system. For problems that occur rapidly, this disparity will introduce uncertainty into the problem analysis that channeling the temperatures through the protection system would avoid. It is also good practice to group all machinery protection parameters (for instance, bearing metal temperatures) into a single, dedicated system, such as a Bently Nevada instrument rack, rather than using the basic process control system for such protective functions.

Shouldn't we wait until after we get the machines purchased and the control system all designed to discuss this?

Machinery monitoring no longer consists only of stand-alone systems. Effective machinery monitoring has always required knowledge of proper transducer selection and mechanical installation, and proper signal-wire shielding and grounding. However, now it is integrated with the control system, emergency shutdown system, plant information system, local area network, and computerized maintenance management system (CMMS), etc. These interfaces can no longer be left as an afterthought of project planning. It saves money to plan for them from the start of the project.

Do project resources really need to be dedicated to coordinating the plant-wide machinery protection and management system?

Yes. Few people would purchase a process control system (such as a large-scale DCS) as simply a box of parts and "do it themselves." The complexity and integration details warrant that people with dedicated skills and experience provide the project-related services to make sure the system works as intended. Machinery protection and management systems are no different. The complexity and integration details in such systems rival those encountered in process control systems.

Summary

By now, I hope you have gained an appreciation for how a machinery management system should be an integral part of all facets of a facility's design. The project disciplines involved in a proper machinery management installation include mechanical, electrical, instrumentation, control system, information technology, and network engineering. Bently Nevada has the multi-disciplined ability to successfully and cost-effectively engineer and install your machinery management system project. We have offices worldwide, giving us the unmatched ability to globally coordinate OEM, design, and fabrication activities. Contact your local Bently Nevada sales or service professional for more information.

References

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